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(54) **Title:** DYNAMIC CONTROL OF PACKET DATA SERVICE THROUGHPUT BY RADIO ACCESS CONTROL NODE

(57) **Abstract:** A radio access network (24) comprises a control node (26) which performs a dynamic adjustment of a priority class afforded to a packet data connection with a user equipment unit. The dynamic adjustment of a priority class performed by the control node is based on a throughput criteria (112) communicated to the control node by the user equipment unit. In one example embodiment, the dynamic adjustment is performed by a dynamic priority regulator application program (100) which executes at node compares actual data packet throughput for the packet data connection with the throughput criteria, and on the basis of the comparison performs a change of the priority class accorded to the packet data connection. In accordance with the change of the priority class the control node requests a radio base station node to change a throughput rate for the packet data connection. The control node performs the dynamic adjustment of a priority class within priority class constraints also communicated to the control node by the user equipment unit.

DYNAMIC CONTROL OF PACKET DATA SERVICE THROUGHPUT BY RADIO ACCESS CONTROL NODE

BACKGROUND

1. FIELD OF THE INVENTION

The present invention pertains to wireless telecommunications, and particularly to controlling throughput of a packet data service over a radio access network.

2. RELATED ART AND OTHER CONSIDERATIONS

In a typical cellular radio system, mobile user equipment units (UEs) communicate via a radio access network (RAN) to one or more core networks. The user equipment units (UEs) can be mobile stations such as mobile telephones ("cellular" telephones) and laptops with mobile termination, and thus can be, for example, portable, pocket, hand-held, computer-included, or car-mounted mobile devices which communicate voice and/or data with radio access network.

The radio access network (RAN) covers a geographical area which is divided into cell areas, with each cell area being served by a base station. A cell is a geographical area where radio coverage is provided by the radio base station equipment at a base station site. Each cell is identified by a unique identity, which is broadcast in the cell. The base stations communicate over the air interface (e.g., radio frequencies) with the user equipment units (UE) within range of the base stations. In the radio access network, several base stations are typically connected (e.g., by landlines or microwave) to a radio network controller (RNC). The radio network controller, also sometimes termed a base station controller (BSC), supervises and coordinates various activities of the plural base stations connected thereto. The radio network controllers are typically connected to one or more core networks.

One example of a radio access network is the Universal Mobile Telecommunications (UMTS) Terrestrial Radio Access Network (UTRAN). The UTRAN is a third generation system which in some respects builds upon the radio access technology known as Global System for Mobile communications (GSM) developed in Europe. UTRAN is essentially a wideband code division multiple access (W-CDMA) system.

As those skilled in the art appreciate, in W-CDMA technology a common frequency band allows simultaneous communication between a user equipment unit (UE) and plural base stations. Signals occupying the common frequency band are discriminated at the receiving station through spread spectrum CDMA waveform properties based on the use of a high speed, pseudo-noise (PN) code. These high speed PN codes are used to modulate signals transmitted from the base stations and the user equipment units (UEs). Transmitter stations using different PN codes (or a PN code offset in time) produce signals that can be separately demodulated at a receiving station. The high speed PN modulation also allows the receiving station to advantageously generate a received signal from a single transmitting station by combining several distinct propagation paths of the transmitted signal. In CDMA, therefore, a user equipment unit (UE) need not switch frequency when handoff of a connection is made from one cell to another. As a result, a destination cell can support a connection to a user equipment unit (UE) at the same time the origination cell continues to service the connection. Since the user equipment unit (UE) is always communicating through at least one cell during handover, there is no disruption to the call. Hence, the term "soft handover." In contrast to hard handover, soft handover is a "make-before-break" switching operation.

The Universal Mobile Telecommunications (UMTS) Terrestrial Radio Access Network (UTRAN) accommodates both circuit switched and packet switched connections. In this regard, in UTRAN the circuit switched connections involve a radio network controller (RNC) communicating with a mobile switching center (MSC), which in turn is connected to a connection-oriented, external core network, which may be (for example) the Public Switched Telephone Network (PSTN) and/or the Integrated Services Digital Network (ISDN). On the other hand, in UTRAN the packet switched connections involve the radio network controller communicating with a Serving GPRS Support Node (SGSN) which in turn is connected through a backbone network and a

Gateway GPRS support node (GGSN) to packet-switched networks (e.g., the Internet, X.25 external networks)

There are several interfaces of interest in the UTRAN. The interface between the radio network controllers (RNCs) and the core network(s) is termed the "Iu" interface. The interface between a radio network controller (RNC) and its base stations (BSs) is termed the "Iub" interface. The interface between the user equipment unit (UE) and the base stations is known as the "air interface" or the "radio interface" or "Uu interface".

Some wireless telecommunications networks have differing priority classes for user access. For example, a mobile system may offer a fixed number of priority access classes to its subscribers. There are several possible techniques for assigning a priority class to a mobile system user.

One technique for assigning priority class is to negotiate a static priority class value for each subscriber at the time of subscription to the mobile system. The negotiated priority class can be stored as part of the subscriber information, e.g., in a record in a home location register or the like associated with the subscriber. The negotiated priority class is correlated with a certain price or cost. A higher priority class entails, of course, a more expensive use of the mobile system, but also an enhanced performance. However, in accordance with this technique, the subscriber will have the same priority class at all times, regardless of likely changing capacity requirements for the subscriber. For example, at one time the subscriber may use only an electronic mail (email) application and would at that time be satisfied with a lower capacity. At another time, on the other hand, the subscriber may wish to execute a video application which has significantly higher throughput capacity requirement. Thus, this first technique can lead to a problem of executing executions that require high priority with a low priority class throughput, and vice versa.

Another technique for assigning priority class is to allow the user to set the priority class needed at the time of the user equipment unit (UE) establishing a connection with the radio access network. A variation on this technique is to allow the user to switch priority class during a session in order to increase or decrease the throughput. In this regard, see United States Patent Application Serial Number

09/032,060, filed February 27, 1998, and its corresponding PCT publication WO99/44379, which are hereby incorporated by reference in their entirety.

While these latter techniques are more efficient particularly at the time of starting the connection, problems still exist. A user may not know what priority class is sufficient. In a lightly loaded system, a low priority class user will receive a rather high throughput but in a heavily loaded system a low priority class user will have low throughput. Moreover, even with the user having the capability of dynamically changing priority classes, the change can be difficult and does require disruptive interaction with the user.

What is needed, therefore, and an object of the present invention, is an efficient and non-disruptive technique for dynamically changing priority class for a data packet connection.

BRIEF SUMMARY OF THE INVENTION

A radio access network comprises a control node which performs a dynamic adjustment of a priority class afforded to a packet data connection with a user equipment unit. The dynamic adjustment of priority class is performed by the control node in accordance with a throughput criteria which is communicated to the control node by the user equipment unit. In one example embodiment, the dynamic adjustment is performed by a dynamic priority regulator application program which executes at the control node. In an illustrated embodiment, the control node is a radio network access controller (RNC) node of the radio access network (URAN).

The dynamic priority regulator function performed by the control node compares actual data packet throughput for the packet data connection with the throughput criteria, and on the basis of the comparison performs a change of the priority class accorded to the packet data connection. In accordance with the change of the priority class the control node requests a radio base station node to change a throughput rate for the packet data connection.

The control node performs the dynamic adjustment of priority class within priority class constraints also communicated to the control node by the user equipment

unit. That is, the user equipment unit (UE) specifies to the dynamic adjustment of a priority class a maximum priority class acceptable to the user equipment unit (UE), so that the subscriber for the user equipment unit (UE) will not be charged for a priority class exceeding the maximum priority class specified by the user equipment unit (UE).

In one embodiment, the radio access network is configured to have a classification of connections comprising a best efforts class and one or more non-best efforts (e.g., fixed) priority classes. Unlike the non-best efforts priority class(es), the best efforts class does not provide a guaranteed service, but instead the users in the "best efforts" class receive the resources left over from guaranteed users (e.g., from connections using the non-best efforts priority classes). In this embodiment, the network is further configured to have plural priority classes within the best efforts class. Further, the adjustment of priority class technique of the invention summarized above concerns a changing of a packet connection between differing priority classes of the best efforts class.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of preferred embodiments as illustrated in the accompanying drawings in which reference characters refer to the same parts throughout the various views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

Fig. 1 is diagrammatic view of example mobile communications system in which the present invention may be advantageously employed.

Fig. 2 is a simplified function block diagram of a portion of a UMTS Terrestrial Radio Access Network, including a user equipment unit (UE) station; a radio network controller; and a base station.

Fig. 3 is a flowchart showing basic steps performed by a dynamic priority regulator function of one example embodiment of the invention.

Fig. 3A is a flowchart showing various substeps of the steps of the function of Fig. 3.

Fig. 4 is a diagrammatic view of a network configuration of priority classes, showing a best efforts class and at least one non-best efforts priority classes.

Fig. 5 is a chart illustrating an example context in which the present invention can be employed.

Fig. 6 is a schematic view of an example RNC node in accordance with one embodiment of the invention.

Fig. 7 is a schematic view of an example base station node in accordance with one embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the present invention. However, it will be apparent to those skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the present invention with unnecessary detail.

The present invention is described in the non-limiting, example context of a universal mobile telecommunications (UMTS) 10 shown in Fig. 1. A representative, connection-oriented, external core network, shown as a cloud 12 may be for example the Public Switched Telephone Network (PSTN) and/or the Integrated Services Digital Network (ISDN). A representative, connectionless-oriented external core network shown as a cloud 14, may be for example the Internet. Both core networks are coupled to their corresponding service nodes 16. The PSTN/ISDN connection-oriented network 12 is connected to a connection-oriented service node shown as a Mobile Switching Center (MSC) node 18 that provides circuit-switched services. The Internet connectionless-oriented network 14 is connected to a General Packet Radio Service (GPRS) node 20 tailored to provide packet-switched type services which is sometimes referred to as the serving GPRS service node (SGSN).

Each of the core network service nodes 18 and 20 connects to a UMTS Terrestrial Radio Access Network (UTRAN) 24 over a radio access network (RAN) interface referred to as the Iu interface. UTRAN 24 includes one or more radio network controllers (RNCs) 26. For sake of simplicity, the UTRAN 24 of Fig. 1 is shown with only one RNC nodes, particularly RNC 26. Each RNC 26 is connected to a plurality of base stations (BS) 28. For example, and again for sake of simplicity, one base station 28 node is shown connected to the example RNC 26 over the Iub interface. It will be appreciated that a different number of base stations can be served by each RNC, and that RNCs need not serve the same number of base stations.

A user equipment unit (UE), such as user equipment unit (UE) 30 shown in Fig. 1, communicates with one or more base stations (BS) 28 over a radio or air interface 32. Each of the radio interface 32, the Iu interface, the Iub interface, and the Iur interface are shown by dash-dotted lines in Fig. 1.

Preferably, radio access is based upon wideband, Code Division Multiple Access (WCDMA) with individual radio channels allocated using CDMA spreading codes. Of course, other access methods may be employed. WCDMA provides wide bandwidth for multimedia services and other high transmission rate demands as well as robust features like diversity handoff and RAKE receivers to ensure high quality. Each user mobile station or equipment unit (UE) 30 is assigned its own scrambling code in order for a base station 28 to identify transmissions from that particular user equipment unit (UE) as well as for the user equipment unit (UE) to identify transmissions from the base station intended for that user equipment unit (UE) from all of the other transmissions and noise present in the same area.

Different types of control channels may exist between one of the base stations 28 and user equipment units (UEs) 30. For example, in the forward or downlink direction, there are several types of broadcast channels including a general broadcast channel (BCH), a paging channel (PCH), a common pilot channel (CPICH), and a forward access channel (FACH) for providing various other types of control messages to user equipment units (UEs). In the reverse or uplink direction, a random access channel (RACH) is employed by user equipment units (UEs) whenever access is desired to perform location registration, call origination, page response, and other types of access

operations. The random access channel (RACH) is also used for carrying certain user data, e.g., best effort packet data for, e.g., web browser applications.

As set up by the control channels, traffic channels (TCH) are allocated to carry substantive call communications with a user equipment unit (UE). Some of the traffic channels can be common traffic channels, while others of the traffic channels can be dedicated traffic channels (DCHs).

The present invention particularly concerns a dynamic priority regulator function 100 which is performed at a control node of the radio access network (URAN) 24. In the illustrated embodiment of Fig. 1, the dynamic priority regulator function 100 is performed by a radio network controller (RNC) 26, e.g., the radio network controller (RNC) 26 serves as the control node. The dynamic priority regulator function 100 can, in other embodiments, be performed at other nodes of a radio access network. As explained hereinafter particularly with regard to the example general steps of Fig. 3, the dynamic priority regulator function 100 performs a dynamic adjustment of a priority class afforded to a packet data connection with user equipment unit (UE) 30 . The packet data connection can be transmitted in conjunction with execution of any of a set 108 of packet data service application programs at user equipment unit (UE) 30.

The dynamic adjustment of a priority class performed by the control node is based on a throughput criteria communicated to the control node by the user equipment unit. The throughput criteria is specified by the user/subscriber using a user throughput interface 110. The user throughput interface 110 can be used not only to specify a throughput criteria, but also a priority class constraint which is also to be communicated to the control node by the user equipment unit. The priority class constraint can be, for example, a maximum priority class acceptable to the user equipment unit (UE), so that the subscriber for the user equipment unit (UE) will not be charged for a priority class exceeding the maximum priority class specified by the user equipment unit (UE). In the illustrated embodiment, both the throughput criteria and the priority class constraint specified using the user throughput interface 110 are communicated via a throughput criteria message 112 to the control node, e.g., to radio network controller (RNC) 26.

For an illustrated embodiment, Fig. 2 shows selected general aspects of user equipment unit (UE) 30 and illustrative nodes such as radio network controller 26 and

base station 28. The user equipment unit (UE) 30 shown in Fig. 2 includes a data processing and control unit 31 for controlling various operations required by the user equipment unit (UE). The UE's data processing and control unit 31 provides control signals as well as data to a radio transceiver 33 connected to an antenna 35. The data processing and control unit 31 includes set 108 of packet data service applications executed by user equipment unit (UE) 30, as well as the user throughput interface 110 through which the user specifies the throughput criteria and priority class constraints which are germane to the present invention. The set 108 of packet data service applications includes, in the illustrated example, a file transfer program (FTP) 322, an electronic mail program (email) 324, and a web browser 326. Other packet data service applications are also within the scope of the present invention, the foregoing list being merely illustrative.

In addition, the user equipment unit (UE) 30 includes an input device 310 and a display screen 320. The input device 310 can be a keyboard or the like; the display screen 320 can be an LCD or LED display, for example.

The example radio network controller 26 and base station 28 as shown in Fig. 2 are radio network nodes that each include a corresponding data processing and control unit 36 and 37, respectively, for performing numerous radio and data processing operations required to conduct communications between the RNC 26 and the user equipment units (UEs) 30. Part of the equipment controlled by the base station data processing and control unit 37 includes plural radio transceivers 38 connected to one or more antennas 39.

In the example embodiment illustrated in Fig. 2, the dynamic adjustment is performed by a dynamic priority regulator application program 200 which executes on the data processing and control unit 36 at the control node (e.g., radio network controller (RNC) 26). The dynamic priority regulator application program 200 includes instructions which, when executed, generally result in performance of at least some of the basic steps depicted in Fig. 3 and Fig. 3A. In addition, the dynamic priority regulator application program 200 includes various registers, including a data packet flow rate register 210, a current priority class register 212, a user equipment unit (UE)-requested throughput register 214, and a user equipment unit (UE)-specified max priority class register 216.

Fig. 3 shows basic actions which occur in conjunction with performance of the dynamic priority regulation of the present invention. In the particular example shown in Fig. 2 and Fig. 3, it is assumed that a connection for a data packet service has already been established. Further, for sake of illustration only, it is assumed that the data packet service for which the connection is established is one of the file transfer program (FTP) 322, the electronic mail program (email) 324, or the web browser 326.

Step 3-0 of Fig. 3 shows transmission of the throughput criteria message 112 from user equipment unit (UE) 30 to radio network controller (RNC) 26. As previously indicated, the throughput criteria message 112 is generated by the user when interacting with user throughput interface 110. In this regard, the user/subscriber of user equipment unit (UE) 30 interacts with input device 310 and display screen 320 of user equipment unit (UE) 30 to specify the throughput criteria and the priority class constraints for the data packet service which is being or will be executed at user equipment unit (UE) 30.

It should also be understood that whereas throughput criteria message 112 is shown as one message which includes both throughput criteria and the priority class constraints, that the throughput criteria and the priority class constraints can be the subject of separate messages. The throughput criteria message 112 can have various formats, and should identify the particular user equipment unit (UE) from which it emanates as well as have a control frame type or the like which identifies the type of message being sent, i.e., the throughput criteria message 112.

At step 3-1 the dynamic priority regulator application program 200 checks for receipt of any initial or new throughput criteria message 112 from user equipment unit (UE) 30. When an initial throughput criteria message 112 is received, the values obtained from the throughput criteria message 112 are employed for subsequent steps of Fig. 3. In subsequent iterations of the loop of steps 3-2 through 3-5 of Fig. 3, if no new throughput criteria message 112 is received, the values for the preceding throughput criteria message 112 are retained for performance of the loop.

As step 3-2, the dynamic priority regulator function 100, and particularly the dynamic priority regulator application program 200 shown in Fig. 2, measures or otherwise assesses/obtains the current throughput of the data packet connection. In this

regard, the dynamic priority regulator application program 200 monitors a data packet buffer 220 for the connection, or otherwise receives an indication of the current data packet flow rate for the connection. The data packet flow rate is stored in the packet flow rate register 210 (see Fig. 2). If required, the dynamic priority regulator function 100 then, as step 3-3, regulates or changes the priority class of the data packet service connection.

More detailed example steps subsumed in step 3-2 and step 3-3 are illustrated in Fig. 3A. Step 3A-2(1) shows dynamic priority regulator application program 200 checking whether the data packet buffer 220 for the connection is empty. If data packet buffer 220 for the connection is empty, at step 3A-2(2) the dynamic priority regulator application program 200 sets the value in current priority class register 212 at zero, thereby according the connection the lowest priority. Since the data packet buffer 220 for the connection is empty, the connection does not require any priority class greater than the lowest, and according the lowest priority class to the connection assures the subscriber of the least cost for the connection so long as the network is able to handle the connection in a manner such that the data packet buffer 220 for the connection is empty.

If the data packet buffer 220 for the connection is not empty, as step 3A-2(3) the dynamic priority regulator application program 200 determines whether the actual throughput for the connection is greater than or equal the requested throughput. The actual throughput for the connection is stored in data packet flow rate register 210, whose value is determined based on a counting of the number of outgoing packets for the connection over time (multiplied by the packet size of each packet). The requested throughput value is stored in the UE-requested throughput register 214, whose value was obtained from the throughput criteria message 112. If the actual throughput for the connection is not greater than or equal to the requested throughput, step 3A-3(1) and step 3A-3(2) are performed prior to returning to step 3A-2(1). If the actual throughput for the connection is greater than or equal to the requested throughput, step 3A-2(4), and possibly step 3A-3(3) and 3A-3(4) are performed prior to returning to step 3A-2(1).

At step 3A-3(1), the dynamic priority regulator application program 200 ascertains whether the value in the current priority class register 212 is the current priority class for the connection is the maximum permitted by the user. The

information for making this comparison, e.g., maximum priority class permitted by the user, is obtained from the UE-specified max priority class register 216. If the value in the current priority class register 212 is not the current priority class for the connection is the maximum permitted by the user, at step 3A-3(2) the dynamic priority regulator application program 200 increments the current priority class for the connection prior to returning to step 3A-2(1). On the other hand, if the value in the current priority class register 212 has reached the maximum permitted by the user, the dynamic priority regulator application program 200 cannot adjust the current priority class and therefore merely returns to step 3A-2(1).

When the actual throughput for the connection is greater than or equal to the requested throughput, as step 3A-2(4) the dynamic priority regulator application program 200 more closely checks whether the actual throughput for the connection is equal to the requested throughput. If equality exists, then no further action need be taken and execution returns to step 3A-2(1). On the other hand, if the actual throughput for the connection exceeds the requested throughput, at step 3A-3(3) the dynamic priority regulator application program 200 checks current priority class register 212 to determine whether the current priority class for the connection is the lowest priority class (e.g., zero). If the determination at step 3A-3(3) is negative, at step 3A-3(4) the dynamic priority regulator application program 200 decrements the value in current priority class register 212, thereby lowering the priority class for the connection and possibly providing the subscriber with a less expensive rate. If the determination at step 3A-3(3) is positive, the lowest priority class has already been achieved, so the dynamic priority regulator application program 200 merely returns to step 3A-2(1).

In situations in which the priority class for the connection has been changed [as can occur, for example, at step 3A-2(2), step 3A-3(2), or step 3A-3(4)], the radio base station (RBS) 28 must be advised that the throughput rate for the connection is to be changed in accordance with the new priority class. Therefore, step 3-4 of Fig. 3 shows the dynamic priority regulator application program 200 sending a message to radio base station (RBS) 28 for advising the radio base station (RBS) 28 to increase or decrease (as the case may be) the throughput rate for the connection.

Step 3-5 of Fig. 3 shows that the dynamic priority regulator application program 200 logs usage of the priority class for billing purposes. Details of step 3-5 are not

shown, but it will be understood that dynamic priority regulator application program 200 keeps a record of the cost of the connection from a priority perspective, indicating how much time the connection consumed at each of the possible plural priority classes which the connection may have utilized at any time. In other words, the dynamic priority regulator application program 200 logs information which permits the system to determine at what priority class a connection began, how long that priority class was utilized, and what other priority classes may have subsequently been utilized (along with the time for which each such subsequent priority class was utilized). The logging action of step 3-5 thus permits the subscriber to be charged appropriately and proportionately for the usage of the one or more priority classes utilized.

Thus, the dynamic priority regulator function 100 performed by the control node 26 compares [at step 3A-2(3)] actual data packet throughput for the packet data connection with the throughput criteria, and on the basis of the comparison performs any necessary change of the priority class accorded to the packet data connection [see, e.g., step 3A-3(2) and step 3A-3(4)]. In accordance with the change of the priority class the control node requests a radio base station node to change a throughput rate for the packet data connection [step 3-4].

The control node performs the dynamic adjustment of a priority class within priority class constraints which are also communicated to the control node by the user equipment unit. That is, the user equipment unit (UE) specifies to the dynamic adjustment of a priority class a maximum priority class acceptable to the user equipment unit (UE), so that the subscriber for the user equipment unit (UE) will not be charged for a priority class exceeding the maximum priority class specified by the user equipment unit (UE).

The preceding discussion has illustrated and employed the concept of priority class in a conventional sense. However, in addition to utilization with conventional priority classes as aforedescribed, the invention further pertains to dynamic adjustment or changing of priority among plural priority classes which constitute a best efforts class, as explained below.

Fig. 4 illustrates conventional priority classes, with each priority class typically having a differing degree of guaranteed quality of service relative to another guaranteed

priority class. For example, connections which have guaranteed priority class GP3 have a higher quality of service (e.g., throughput value) than connections allocated to guaranteed priority class GP2, and so forth. Fig. 4 further illustrates a best efforts class (BE). Connections allocated to the best efforts class (BE) share resources left over from connections having the non-best efforts priority class(es), e.g., resources left over after connections belonging to priority classes P1 -P3.

In accordance with the present invention, the best efforts class (BE) comprises plural best efforts priority classes (BEP1, BEP2, BEP3) [in a sense, a number of best efforts "subclasses"]. In the best efforts hierarchy, connections which have best efforts priority class BEP3 have a higher quality of service (e.g., throughput value) than connections allocated to best efforts BEP2, and so forth. In other words, the higher priority a best efforts user has, the more throughput that user receives relative to other best efforts users.

In connection with Fig. 4, Fig. 5 illustrates graphically an example, non-limiting situation in which the present invention can be employed. The graph of Fig. 5 shows the maximum power output for a base station 28 being set at the example value of twenty watts. At time t0, the guaranteed users consume only 5 watts of output power. The output power consumed by the guaranteed users is shown by the broken line in Fig. 5. At time t0, 15 watts are available for the best efforts users. If there are three best efforts users connected to the system at time t0 and all users have the best efforts priority class BE1, each of these three best efforts users receive 5 watts. For simplicity, in this discussion it is assumed that one watt corresponds to 50 kbit/s. This means that, at time t0, all best efforts users receive 250 kbit/s. If one of the users has a throughput demand of 150 kbit/s, that user is satisfied at time t0.

At time t2 in Fig. 5, the load from the guaranteed users increases to 15 watts, so at time t2 the best efforts users have only 5 watts to share (a total of 250 kbit/s to share). If the power is linearly divided among the priority classes, the user that demanded 150 kbit/s is not satisfied. In this regard, the user that demanded 150 kbit/s needs to increase his priority class to priority class BE3 in order to receive 150 kbit/s (e.g., 3*250/5, where 3 is the user's priority after the increase, 250 is the amount of throughput available, and 5 is the sum of all best efforts user's priorities).

In the Fig. 4 and Fig. 5 embodiment, the invention is particularly applicable to the FACH and Shared downlink channel.

The steps performed in Fig. 3 and Fig. 3A for describing a dynamic change of priority class generally, as well as the discussion pertaining to the remaining figures, are equally applicable for describing a dynamic change of best efforts user priority class. The non-limiting example embodiment of Fig. 4 and Fig. 5 is but a special case of the generalized invention, wherein in the embodiment of Fig. 4 and Fig. 5 the term "priority class" encompasses a best efforts priority class.

As explained previously, it may require considerable interaction for the user per se to regulate the priority class in a constantly changing resource situation. The present invention overcomes this problem by allowing the dynamic priority regulator function 100 supervise the current throughput for the running applications. All the user need to do is to set a desired throughput level per application (e.g., using the throughput criteria message 112) and let the dynamic priority regulator function 100 regulate towards this value.

The priority class constraint parameter of the present invention prevents all best efforts users from having their priority classes raised identically in the situation described above, assuming that the priority class constraints are set differently by different users. In view of the priority class constraints, the dynamic priority regulator function 100 is allowed to regulate priority class allocation only up to the maximum priority class value specified as being financially acceptable to the user. This upper limit value typically differs among users, since the higher priority a service receives increases its cost. For example, a user with a small budget may set an upper limit much lower than a user with a higher budget, and therefore the priorities in the system will be different even at a high system load time.

Thus, in accordance with one aspect of the present invention, static priority classes can be complemented with a flexible dynamic priority class having priority subclasses which are changeable for a connection by dynamic priority regulator function 100. Moreover, with the present invention quality of a connection can be changed depending on situation and application.

Fig. 6 illustrates, in somewhat more detail, an example non-limiting RNC node 26 of the present invention. It so happens that the RNC node 26 of Fig. 6 is a switched-based node having a switch 120. The switch 120 serves to interconnect other constituent elements of RNC node 26. Such other constituent elements include extension terminals 122_1 through 122_n, as well as extension terminal 124. Extension terminals 122_1 through 122_n essentially function to connect RNC node 26 to the base stations 28 served by RNC node 26; extension terminal 124 connects RNC node 26 across the Iu interface to the core network.

Yet other constituent elements of RNC node 26 include diversity handover unit 126; an ALT unit 128; codex 130; timing unit 132; a data services application unit 134; and, a main processor 140. The person skilled in the art will appreciate generally the functions of these constituent elements, it being noted that the ALT unit 128 is a unit which provides, e.g., multiplexing and demultiplexing and (optionally) queuing with regard to differing protocols of cells. In the example embodiment of Fig. 6, the dynamic priority regulator application program 200 is executed by main processor 140 of radio network controller (RNC) 26.

Fig. 7 illustrates, in non-limiting manner, more details of an example base station (BS) node 28 in accordance with one embodiment of the present invention. As with RNC node 26, the base station (BS) node 28 of Fig. 7 is a switched-based node having a switch 220 which serves to interconnect other constituent elements of base station (BS) node 28. Such other constituent elements include extension terminal 222; ALT unit 228; BS main processor 240, and interface boards 242.

Extension terminal 222 connects base station (BS) node 28 to radio network controller (RNC) node 26, and thus comprises the Iub interface. As in the case of radio network controller (RNC) node 26, the ALT unit 228 is a unit which provides, e.g., multiplexing and demultiplexing and (optionally) queuing with regard to differing protocols of cells.

The embodiment of base station (BS) node 28 illustrated in Fig. 7 is housed in a rack having multiple subracks. Each subrack has one or more boards, e.g., circuit boards, mounted thereon. A first subrack 250 contains boards for each of extension terminal 222; ALT unit 228; BS main processor 240, and interface boards 242. Each of

the interface boards 242 is connected to a board on another subrack, e.g., one of the transmitter boards 260 or one of the receiver boards 270. Each receiver board 270 is connected to share certain transmitter/receiver resources in a corresponding transmitter board 260, with the transmitter board 260 being connected to a corresponding one of amplifiers and filters board 280. The amplifiers and filters board 280 is connected to an appropriate antenna 39. For example, interface board $242_{1\text{-}T}$ is connected to transmitter board 260_1, while interface board $242_{1\text{-}R}$ is connected to receiver board 270_1. The pair of transmitter board 260_1 and receiver board 270_1 is, in turn, connected to amplifiers and filters board 280_1. Similar connections exist for a second pairing of transmitter board 260_2 and receiver board 270_2, which interface via interface board $242_{2\text{-}T}$ and interface board $242_{2\text{-}R}$, respectively. Each transceiver 38 of Fig. 2 thus comprises a subrack which includes a transmitter board 260, a receiver board 270, and amplifiers and filters board 280.

In one example embodiment, base station (BS) node 28 is an ATM-based node, with interface boards 242 performing various ATM interfacing functions. The transmitter boards 260 and receiver boards 270 each include several devices. For example, each transmitter board 260 includes unillustrated elements such as an interface connected to its corresponding interface board 242; an encoder; a modulator; and, a baseband transmitter. In addition, the transmitter board 260 includes the transmitter/receiver sources which it shares with receiver board 270, including a D/G transmitter and an radio frequency transmitter. Each receiver board 270 includes unillustrated elements such as an interface connected to its corresponding interface board 242; a decoder; a demodulator; and a baseband receiver. Each amplifiers and filters board 280 includes amplifiers, such as MCPA and LNA amplifiers.

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

WHAT IS CLAIMED IS:

1. A radio access network (24) comprising a control node (26) within the radio access network which performs a dynamic adjustment of a priority class afforded to a packet data connection with a user equipment unit (30) based on a throughput criteria (112) communicated to the control node by the user equipment unit.

2. The apparatus of claim 1, wherein the dynamic adjustment is performed by a dynamic priority regulator application program (100) which executes at the control node.

3. The apparatus of claim 1, wherein the dynamic priority regulator application program (100) compares actual data packet throughput for the packet data connection with the throughput criteria, and on the basis of the comparison performs a change of the priority class accorded to the packet data connection.

4. The apparatus of claim 3, wherein in accordance with the change of the priority class the control node requests a radio base station node (28) to change a throughput rate for the packet data connection.

5. The apparatus of claim 1, wherein the control node performs the dynamic adjustment of a priority class within priority class constraints also communicated to the control node by the user equipment unit.

6. The apparatus of claim 1, wherein the control node is a radio network access controller (RNC) node (26).

7. The apparatus of claim 1, wherein the radio access network is configured to have a best efforts class and one or more non-best efforts priority classes, wherein connections allocated to the best efforts class share resources left over from connections having the non-best efforts priority class(es), wherein the best efforts class comprises plural best efforts priority classes, and wherein the dynamic adjustment of claim 1 is performed with respect to at least one of the best efforts priority classes.

8. A radio access network (24) comprising:

a user equipment unit (30);

a radio base station node (28) which communicates over an air interface with the user equipment unit;

a control node (26) which controls a packet data connection over the air interface with the user equipment unit;

a dynamic priority regulator (100) at the control node which performs a dynamic adjustment of a priority class afforded to the packet data connection with the user equipment unit based on a throughput criteria (112) communicated to the control node by the user equipment unit.

9. The apparatus of claim 8, wherein the dynamic priority regulator compares actual data packet throughput for the packet data connection with the throughput criteria, and on the basis of the comparison performs a change of the priority class accorded to the packet data connection.

10. The apparatus of claim 9, wherein in accordance with the change of the priority class the control node requests the radio base station node to change a throughput rate for the packet data connection.

11. The apparatus of claim 8, wherein the control node performs the dynamic adjustment of a priority class within priority class constraints also communicated to the control node by the user equipment unit.

12. The apparatus of claim 8, wherein the control node is a radio network access controller (RNC) node.

13. The apparatus of claim 8, wherein the radio access network is configured to have a best efforts class and one or more non-best efforts priority classes, wherein connections allocated to the best efforts class share resources left over from connections having the non-best efforts priority class(es), wherein the best efforts class comprises plural best efforts priority classes, and wherein the dynamic adjustment of claim 8 is performed with respect to at least one of the best efforts priority classes.

14. A method of operating a radio access network (24) comprising:

communicating from a user equipment unit (30) to a control node (26) of the radio access network a throughput criteria (112) for a packet data connection; and

at the control node within the radio access network, performing a dynamic adjustment of a priority class afforded to the packet data connection based on the throughput criteria.

15. The method of claim 14, further comprising performing the dynamic adjustment using a dynamic priority regulator application program (100) which executes at the control node.

16. The method of claim 14, wherein the dynamic priority regulator application program performs the steps of:

comparing an actual data packet throughput for the packet data connection with the throughput criteria; and

on the basis of the comparison, performing a change of the priority class accorded to the packet data connection.

17. The method of claim 16, further comprising, in accordance with the change of the priority class, the control node requesting a radio base station node to change a throughput rate for the packet data connection.

18. The method of claim 14, further comprising the control node performing the dynamic adjustment of a priority class within priority class constraints also communicated to the control node by the user equipment unit.

19. The method of claim 14, wherein the radio access network is configured to have a best efforts class and one or more non-best efforts priority classes, wherein connections allocated to the best efforts class share resources left over from connections having the non-best efforts priority class(es), wherein the best efforts class comprises plural best efforts priority classes, and further comprising performing the dynamic adjustment of claim 14 with respect to at least one of the best efforts priority classes.

20. A radio access network (24) having a control node (26) with which a data packet connection with a user equipment unit (30) is established, the network comprising:

a priority class structure comprising a best efforts class and one or more non-best efforts priority classes, wherein connections allocated to the best efforts class share resources left over from connections having the non-best efforts priority class(es), wherein the best efforts class comprises plural best efforts priority classes.

21. The apparatus of claim 20, wherein the control node performs a dynamical adjustment of which of the plural best efforts priority classes is allocated to the connection based on a throughput criteria communicated to the control node by the user equipment unit.

22. The apparatus of claim 21, wherein the dynamic adjustment is performed by a dynamic priority regulator application program (100) which executes at the control node.

23. The apparatus of claim 21, wherein the dynamic priority regulator application program compares actual data packet throughput for the packet data connection with the throughput criteria, and on the basis of the comparison performs a change of the best efforts priority class accorded to the packet data connection.

24. The apparatus of claim 23, wherein in accordance with the change of the priority class the control node requests a radio base station node (28) to change a throughput rate for the packet data connection.

25. The apparatus of claim 21, wherein the control node performs the dynamic adjustment of the best efforts priority class within priority class constraints also communicated to the control node by the user equipment unit.

26. The apparatus of claim 21, wherein the control node is a radio network access controller (RNC) node.

27. A method of operating a radio access network (24) comprising:

configuring a priority class structure to comprise a best efforts class and one or more non-best efforts priority classes, wherein connections allocated to the best efforts class share resources left over from connections having the non-best efforts priority class(es), wherein the best efforts class comprises plural best efforts priority classes.

28. The method of claim 27, further comprising performing a dynamical adjustment of which of the plural best efforts priority classes is allocated to the connection based on a throughput criteria (112) communicated to a control node (26) by the user equipment unit (30).

29. The method of claim 28, further comprising performing the dynamic adjustment using a dynamic priority regulator application program (100) which executes at a control node of the radio access network.

30. The method of claim 29, wherein the dynamic priority regulator application program performs the steps of:

comparing an actual data packet throughput for the packet data connection with the throughput criteria; and

on the basis of the comparison, performing a change of the best efforts priority class accorded to the packet data connection.

31. The method of claim 28, further comprising, in accordance with the change of the best efforts priority class, the control node requesting a radio base station node (28) to change a throughput rate for the packet data connection.

32. The method of claim 28, further comprising the control node performing the dynamic adjustment of a priority class within priority class constraints also communicated to the control node by the user equipment unit.

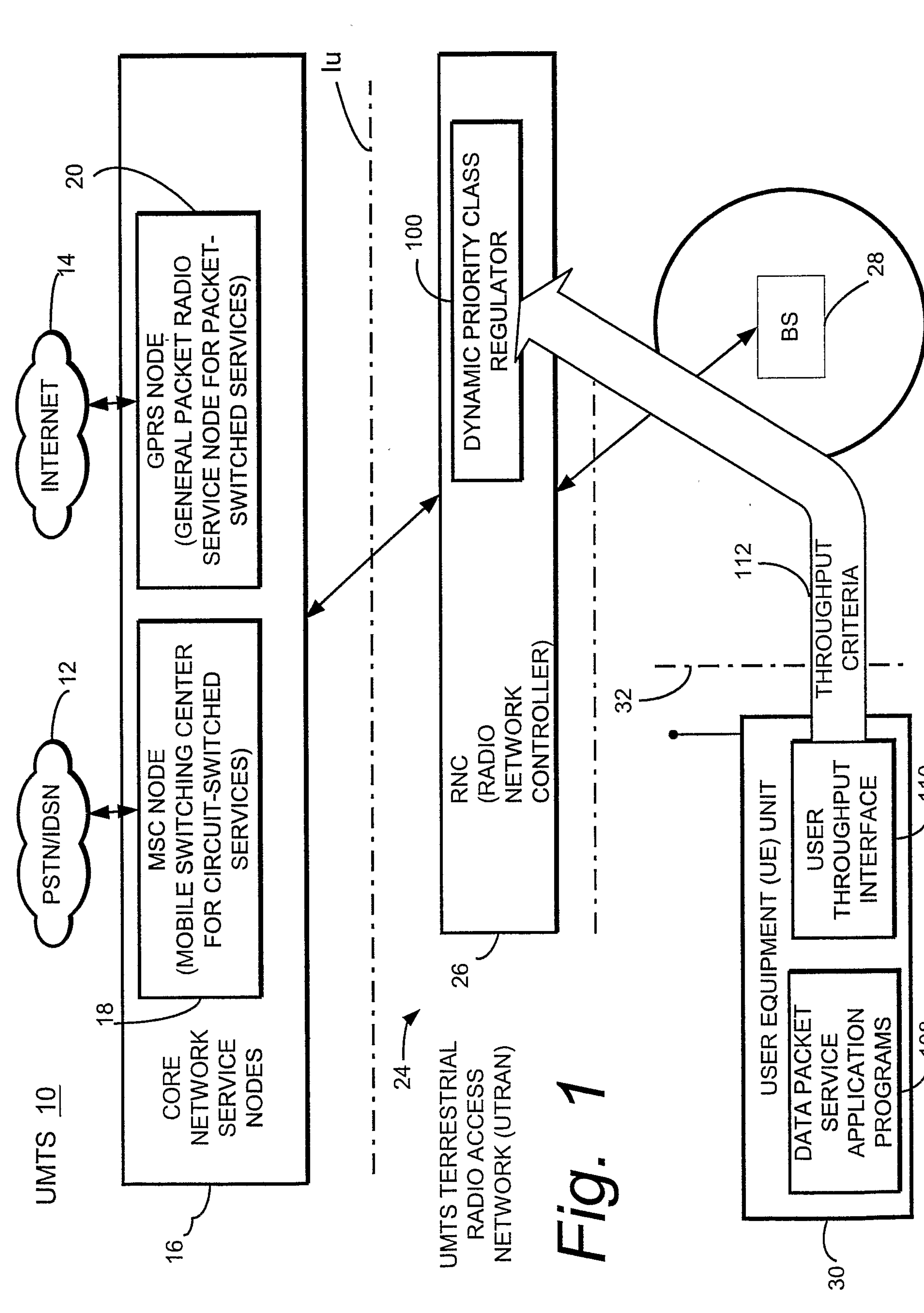

UMTS 10
CORE NETWORK SERVICE NODES
16
PSTN/IDSN
12
INTERNET
14
MSC NODE (MOBILE SWITCHING CENTER FOR CIRCUIT-SWITCHED SERVICES)
18
GPRS NODE (GENERAL PACKET RADIO SERVICE NODE FOR PACKET-SWITCHED SERVICES)
20
Iu
UMTS TERRESTRIAL RADIO ACCESS NETWORK (UTRAN)
24
RNC (RADIO NETWORK CONTROLLER)
26
DYNAMIC PRIORITY CLASS REGULATOR
100
BS
28
THROUGHPUT CRITERIA
112
32
USER EQUIPMENT (UE) UNIT
30
DATA PACKET SERVICE APPLICATION PROGRAMS
108
USER THROUGHPUT INTERFACE
110

Fig. 1

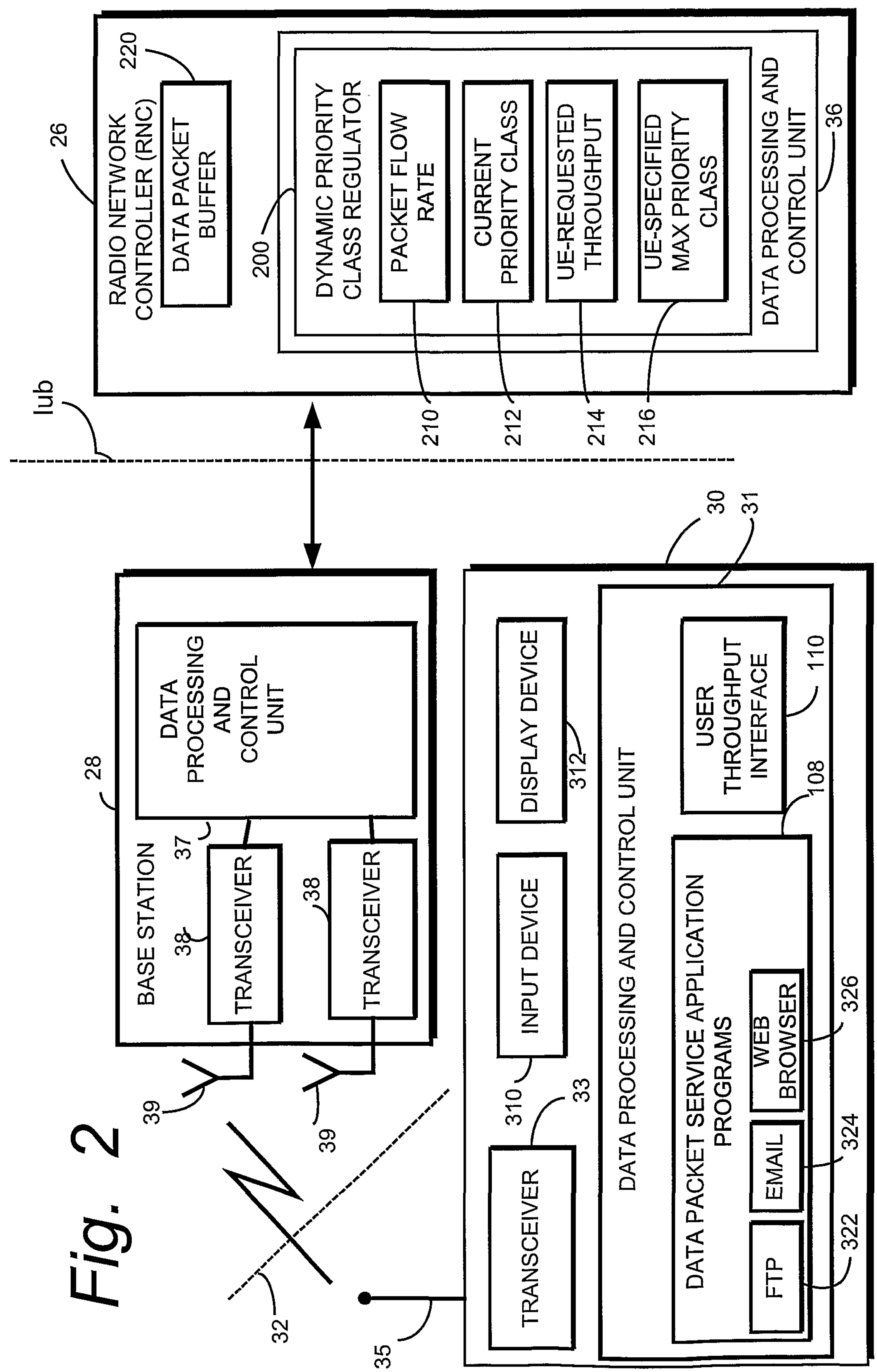

RADIO NETWORK CONTROLLER (RNC)
26
DATA PACKET BUFFER
220
DYNAMIC PRIORITY CLASS REGULATOR
200
PACKET FLOW RATE
CURRENT PRIORITY CLASS
UE-REQUESTED THROUGHPUT
UE-SPECIFIED MAX PRIORITY CLASS
DATA PROCESSING AND CONTROL UNIT
36
210
212
214
216
Iub
BASE STATION
28
DATA PROCESSING AND CONTROL UNIT
37
TRANSCEIVER
38
TRANSCEIVER
38
39
39
32
35
TRANSCEIVER
310
33
INPUT DEVICE
DISPLAY DEVICE
312
DATA PROCESSING AND CONTROL UNIT
30
31
USER THROUGHPUT INTERFACE
110
108
DATA PACKET SERVICE APPLICATION PROGRAMS
FTP
EMAIL
WEB BROWSER
322
324
326

Fig. 2

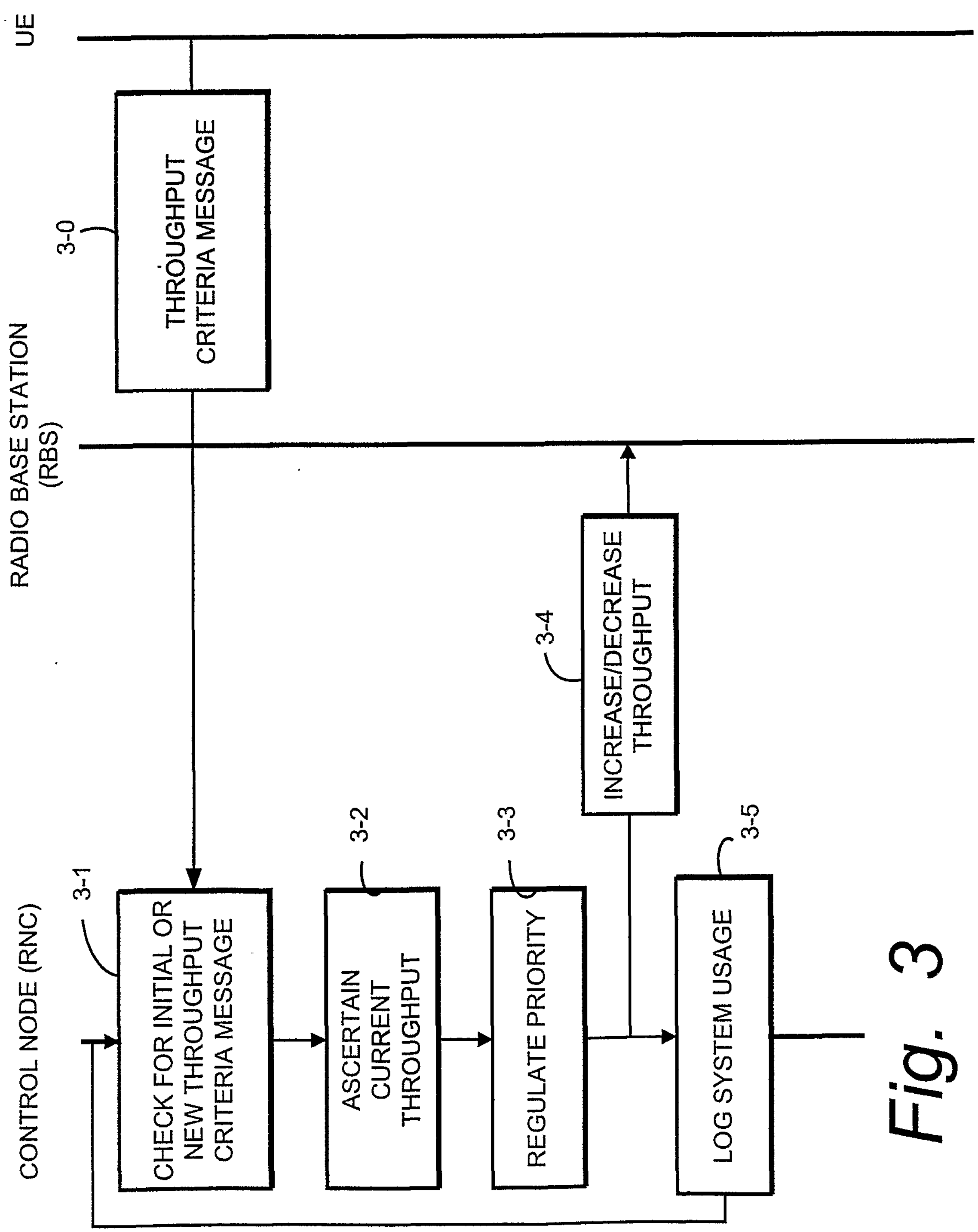
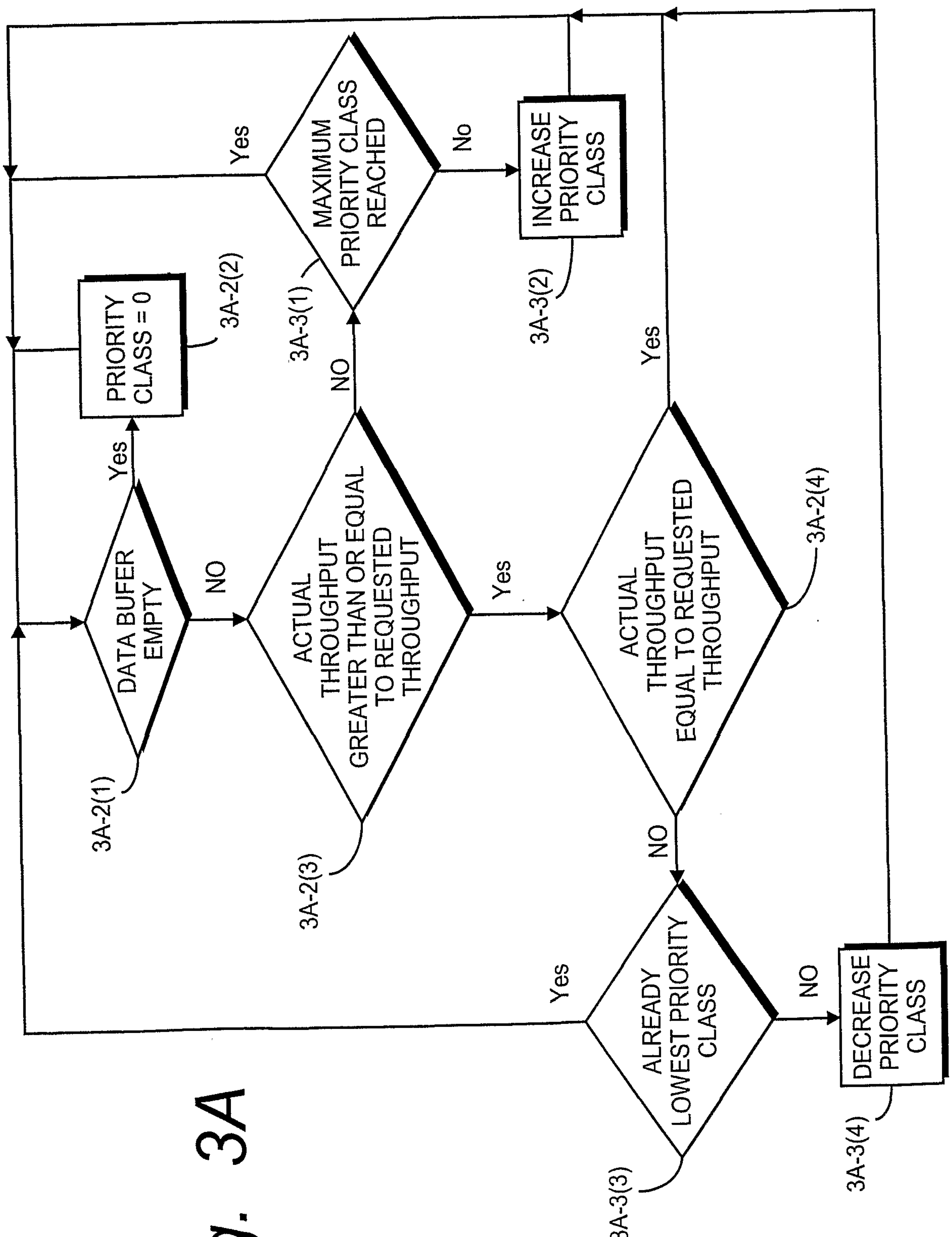

UE
RADIO BASE STATION
(RBS)
CONTROL NODE (RNC)
3-0
THROUGHPUT
CRITERIA MESSAGE
3-1
CHECK FOR INITIAL OR
NEW THROUGHPUT
CRITERIA MESSAGE
3-2
ASCERTAIN
CURRENT
THROUGHPUT
3-3
REGULATE PRIORITY
3-4
INCREASE/DECREASE
THROUGHPUT
3-5
LOG SYSTEM USAGE

Fig. 3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3A-2(1)
Yes
NO
PRIORITY CLASS = 0
3A-2(2)
ACTUAL THROUGHPUT GREATER THAN OR EQUAL TO REQUESTED THROUGHPUT
3A-2(3)
NO
Yes
MAXIMUM PRIORITY CLASS REACHED
3A-3(1)
Yes
No
INCREASE PRIORITY CLASS
3A-3(2)
ACTUAL THROUGHPUT EQUAL TO REQUESTED THROUGHPUT
3A-2(4)
Yes
NO
ALREADY LOWEST PRIORITY CLASS
3A-3(3)
Yes
NO
DECREASE PRIORITY CLASS
3A-3(4)

Fig. 3A

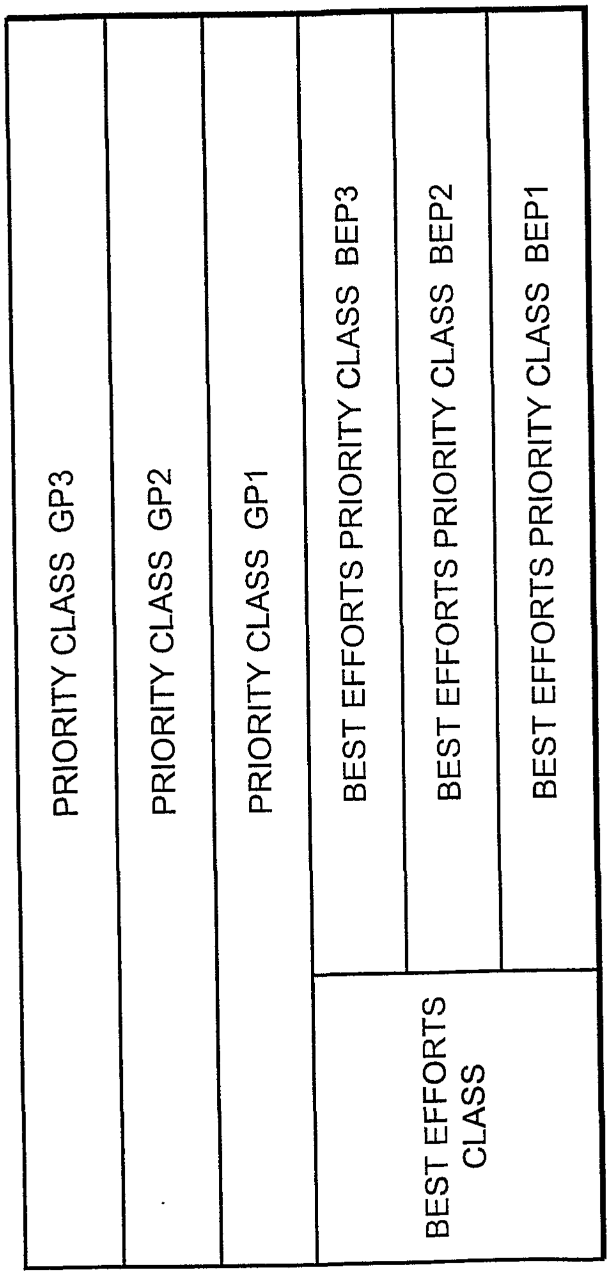

PRIORITY CLASS GP3
PRIORITY CLASS GP2
PRIORITY CLASS GP1
BEST EFFORTS PRIORITY CLASS BEP3
BEST EFFORTS PRIORITY CLASS BEP2
BEST EFFORTS PRIORITY CLASS BEP1
BEST EFFORTS CLASS

Fig. 4

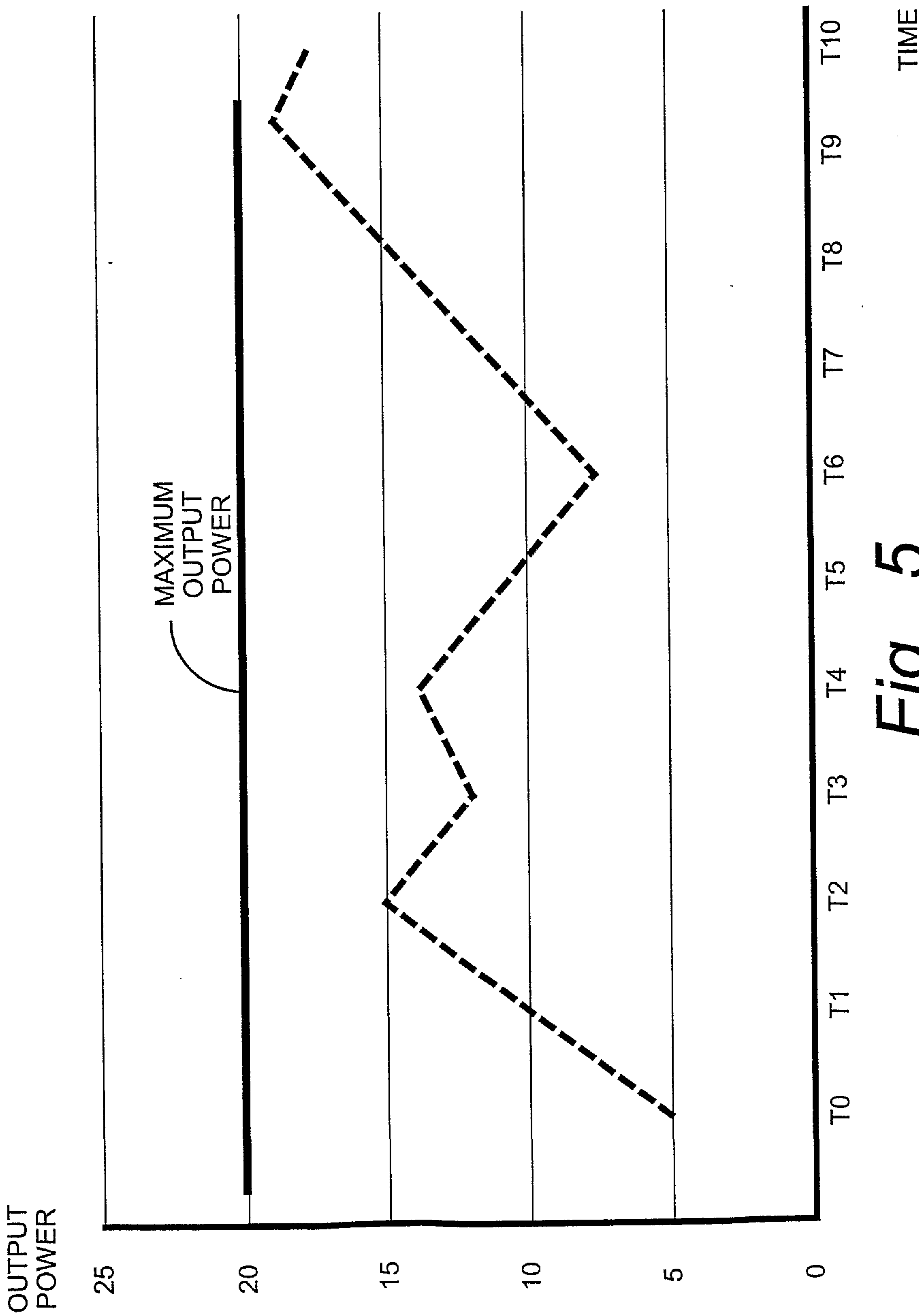

OUTPUT POWER
25
20
15
10
5
0
MAXIMUM OUTPUT POWER
T0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
TIME

Fig. 5

Fig. 6

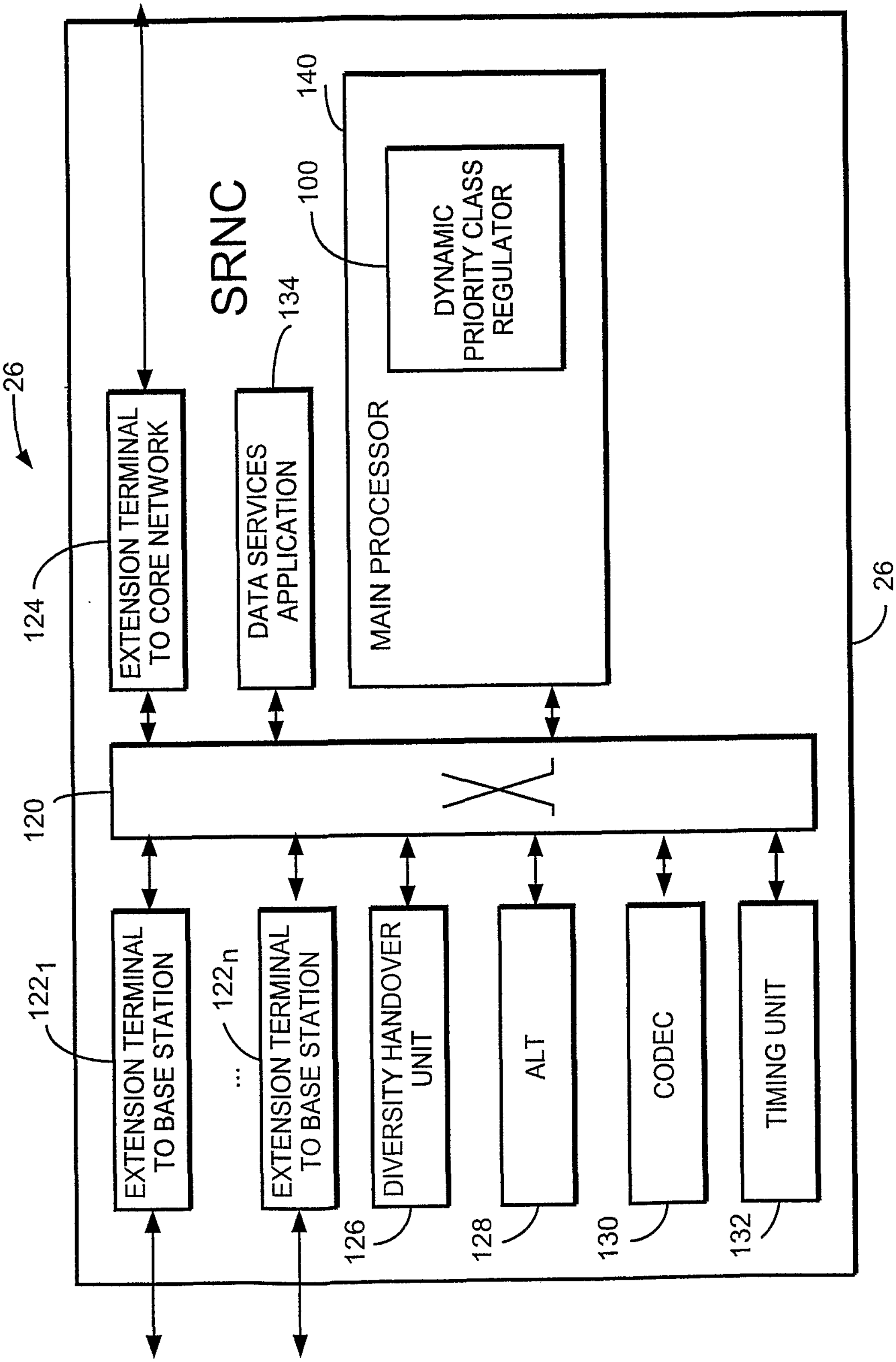
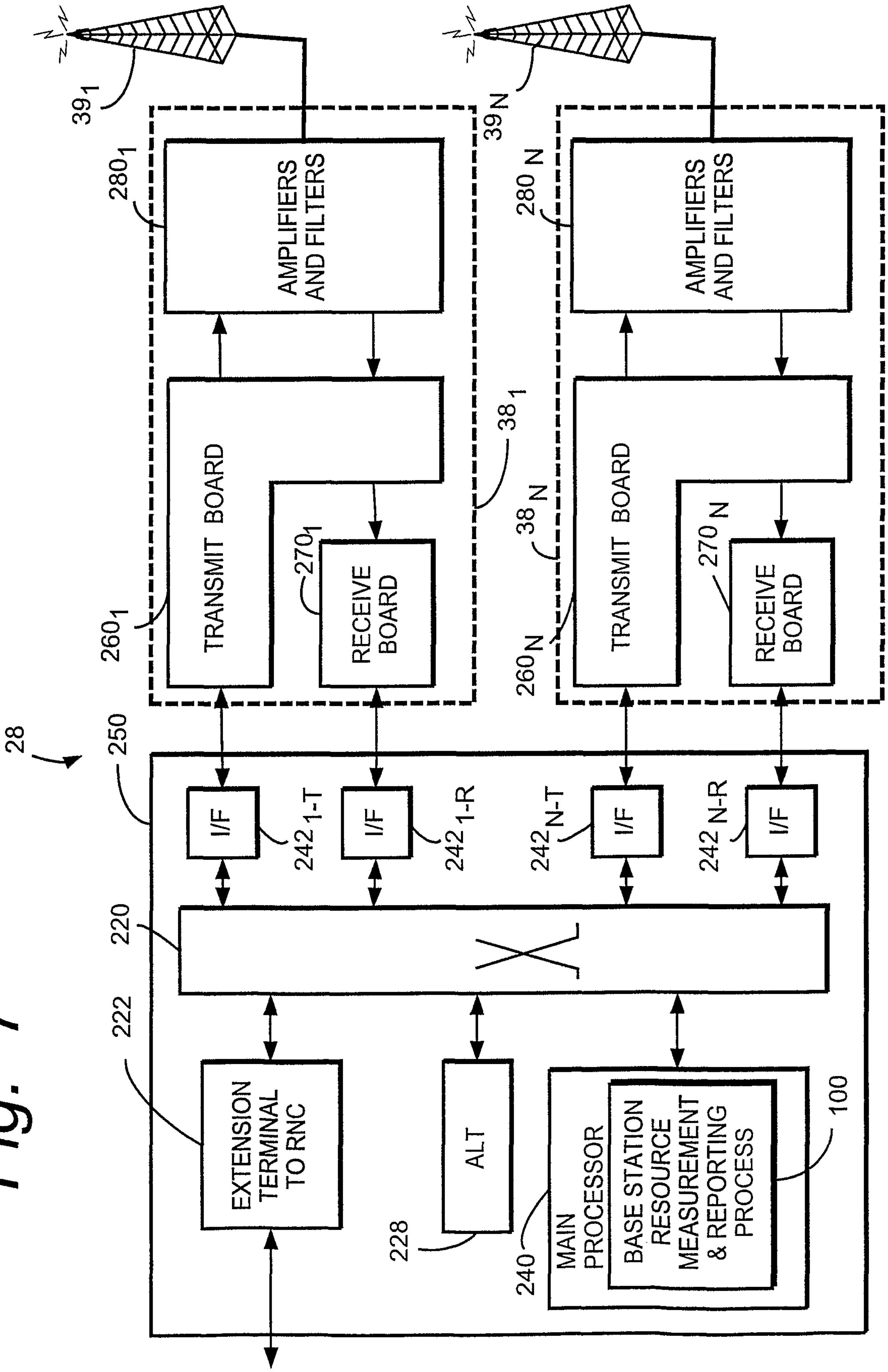

26
SRNC
EXTENSION TERMINAL TO CORE NETWORK
124
DATA SERVICES APPLICATION
134
MAIN PROCESSOR
140
DYNAMIC PRIORITY CLASS REGULATOR
100
120
EXTENSION TERMINAL TO BASE STATION
122₁
...
EXTENSION TERMINAL TO BASE STATION
122n
DIVERSITY HANDOVER UNIT
126
ALT
128
CODEC
130
TIMING UNIT
132
26

Fig. 7


28
39_1
39_N
280_1
AMPLIFIERS AND FILTERS
280 N
AMPLIFIERS AND FILTERS
38_1
38_N
TRANSMIT BOARD
260_1
270_1
RECEIVE BOARD
TRANSMIT BOARD
260_N
270 N
RECEIVE BOARD
250
I/F
$242_{1\text{-}T}$
I/F
$242_{1\text{-}R}$
$242_{N\text{-}T}$
I/F
$242_{N\text{-}R}$
I/F
220
222
EXTENSION TERMINAL TO RNC
ALT
228
MAIN PROCESSOR
240
BASE STATION RESOURCE MEASUREMENT & REPORTING PROCESS
100